THE EFFECT OF DIRECTION, MAGNITUDE, AND DURATION OF BODY TILT ON SIZE ESTIMATION WITH VARIED SURROUND CONDITIONS

By

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BACKGROUND AND HYPOTHESES

This study investigates the effect of variations in the direction, extent, and duration of body tilt on the estimation of lengths of lines, when the lines are presented with different surrounds.

As man moves further into the jet and space age, knowledge of principles concerning perception of cues under adverse or unusual circumstances becomes more crucial if man as an operator is to exercise some control over his vehicle. Wilbanks states that the "capacity to make correct assessment of the physical situation" (1961, p. 63), is one of the most important problems in the control of any machine. The findings that at high altitudes red and green stimuli appear colorless (Matheny, 1961, p. 101), and that size appears to affect judgment of movement differentially when orientation cues for direction are absent (Grether, 1962), are examples of specific visual perceptual problems the space traveler faces. This study approaches the solution of certain of these problems by examining the joint effect of visual and proprioceptive stimulation on estimation of perceptual size.

This experiment also considers certain aspects of a persistent question in perception, viz., the effect of a surround or field on perceptual experience. Although Ittelson (1960, p. 46) considers the "absolute versus relational dichotomy unnecessary," the question of absolute versus relational learning is still of concern in various discrimination and transposition experiments (Gonzales, Gentry, & Bitterman, 1954; Kimble, 1961, pp. 378-382; Spence, 1942).

Several experiments have appeared within the past three decades which support the theory that the perception of size, speed, and color are relationally determined (Brown, 1931; Helson, 1938; Kunnapas, 1955; Rock & Ebenholtz, 1959; Wallach, 1948). The Kunnapas (1955) and Rock and Ebenholtz (1959) experiments are particularly pertinent to the present study because these experiments demonstrated that phenomenal size varied as a function of the surround. Based on this evidence, the present study hypothesizes that size estimates under relational conditions are larger than estimates under nonrelational conditions, and that this relation holds even when the body is tilted.

This experiment also constitutes an extension of the Werner and Wapner (1949) sensory-tonic field theory of perception. This theory postulates that perception is the result of interaction between sensory and motor factors, or that the factors contributing to perception are tonic as well as sensory, in which tonic refers to motion, posture, or somatic states of the perceiver. The proponents, in support of this theory, demonstrated that a simple perceptual task, visual perception of verticality, was significantly affected by degree of magnitude of body tilt (Werner & Wapner, 1952; Werner, Wapner, & Chandler, 1951). Werner _et al_. (1951) showed that degree of displacement of the apparent vertical was proportional to the degree of body tilt, but asserted that the crucial postural factor was the degree of muscular involvement and not magnitude of tilt _per se_. In addition, the sensory-tonic theory postulate of "functional equivalence" asserts that "diverse stimuli . . . lead to identical perceptual end-products" (Wapner & Werner, 1957, p. 3). In support of this postulate, Werner _et al_. (1951) found direction of body tilt did not affect the perception of verticality. Solley (1956) also found direction of tilt did not affect accuracy of postural vertical estimation.

From these results and the sensory-tonic theory, certain predictions may be made concerning two of the variables considered in this experiment, direction and magnitude of body tilt. Relational and nonrelational size estimation should be unrelated to direction of body tilt. In view of the assertion that greater muscular involvement led to increased displacement of the apparent vertical, it is hypothesized that size estimates differ significantly for different magnitudes of body tilt. Further, Comalli, Wapner, and Werner (1959) demonstrated that apparent tactual size was smaller with than without muscular involvement. When this evidence is jointly considered with the data of Rock and Ebenholtz (1959) on surround effects, the preceding hypothesis may be extended. It is predicted that either or both relational or nonrelational visual size estimates decrease with an increase in magnitude of body tilt.

The present study also investigates the effect of sustained body disorientation on the performance of a perceptual task. It examines the relationship between accuracy of size estimation and duration of bodily tilt.

Gibson (1937) demonstrated that a tilted line becomes progressively less tilted during continued inspection time, or in the present context, that accuracy of visual perceptual judgment increased with increased duration. Other studies (Mann & Passey, 1951; Passey & Guedry, 1949) involving proprioceptive perceptual judgment, found accuracy of estimation of the postural vertical decreased with continued exposure to body tilt, during a one-minute period. Mann and Passey (1951) predicted errors of estimation would increase for longer exposure periods.

Based on the preceding evidence, it is hypothesized that the slopes of the functions relating relational and nonrelational size estimation to duration of body tilt are not equal to zero. In contrast to Mann and Passey (1951), in the situation where both visual and proprioceptive factors are involved, it is predicted that accuracy of size estimation increases with increased duration of bodily tilt.

In review, the present experiment investigates the effect of direction, magnitude, and duration of body tilt on size estimation of stimuli with different surround conditions. The study is generally outlined within the framework of certain results from Rock and Ebenholtz (1959) on relational size estimation, and the Werner and Wapner (1949) sensory-tonic theory of perception. An attempt is made to extend the sensory-tonic theory to a more complex perceptual category. In addition, it considers certain aspects of sensory adaptation. The following specific hypotheses are examined.

1. Surround. It is predicted that size estimates made of standard and comparison lines inclosed in luminous rectangles (i.e. relational), will be larger than estimates made of lines not so inclosed (i.e. nonrelational), and that this relation holds even when the body is tilted.

2. Direction of Body Tilt. It is predicted that relational and nonrelational size estimation is unrelated to direction of body tilt.

3. Magnitude of Body Tilt. It is hypothesized that size estimates differ significantly for different magnitudes of body tilt. Additionally, it is predicted that either or both relational or nonrelational size estimates decrease with an increase in degree of body tilt.

4. Duration of Body Tilt. It is predicted that accuracy of size estimation increases with increased duration of exposure to body tilt.

EXPERIMENTAL DESIGN

Apparatus

The apparatus consisted of two main parts, a tilting chair and equipment for stimulus presentation. The apparatus was located in a quiet, dark room, in the center of a semicircular curtained area. The dark curtained area made a homogenous background for the stimulus presentation equipment and eliminated visual cues of the gravitational vertical. The essential elements of the tilting chair and stimulus presentation equipment were as follows.

Tilting Chair. The chair was of simple wooden construction, with a base so devised as to permit different magnitudes of body tilt in left, right, and forward directions. (See Figure 1.) Although Werner et al. (1951) found unsupported body tilt led to more significant displacement of the apparent vertical than supported body tilt, the present body tilt apparatus provided buttock supports and handholds to help S keep from sliding off the chair when tilted. This semisupported arrangement required progressively greater effort by S in order to retain his seating with increased magnitude of body tilt, yet lessened apprehension of falling.

A fitted adjustable headrest with a foam rubber lining was attached to the chair back to eliminate extraneous auditory stimulation and insure that S's head was tilted in the same direction and degree of magnitude as the chair. A bar projecting forward from the bottom center of the chair foot rest was bent sharply upward at a distance of 5 ft. from the back of the chair. The vertical portion of this bar was extendible and at its tip was a pivot, to which a rack that held the stimulus presentation equipment was fastened.

Through the preceding arrangement, the distance from S to stimuli was held constant, and the stimulus presentation equipment was in the same relative degree of tilt as the chair. By rotation or extension of the rack attached to the pivot, any desired inclination of the stimulus lines could be attained. Thus an S with his head in the headrest, always had the center of the stimulus presentation equipment presented directly in front of his face, regardless of direction and magnitude of body tilt. Presentation of stimuli in this manner reduced excessive eye movements, and held visual angle and the angle from which the lines were viewed the same for the various experimental conditions.

Stimulus Presentation Equipment. The equipment used for presentation of the stimuli for making size estimates was a modification of the apparatus used by Rock and Ebenholtz (1959). The equipment for both the relational and nonrelational tasks was constructed as separate self-contained panels (see Figure 2), which could be quickly exchanged as required for S to make the appropriate estimate. Dimensions and characteristics of the stimulus equipment are given in Table 1.

TABLE 1

DIMENSIONS OF THE STIMULUS PRESENTATION EQUIPMENT

ELEMENT	DIMENSIONS RELATIONAL	 NONRELATIONAL
Stimulus panel	32 x 40	32 x 40
Standard line[a]	$\frac{1}{2}$ x 6	$\frac{1}{2}$ x 6
Variable line[a]	$\frac{1}{2}$ x 18	$\frac{1}{2}$ x 18
Distance between lines	24	24
Rectangular outlines[b]		
Rectangle inclosing standard line	4 x 7	none
Rectangle inclosing variable line	12 x 21	none
Transposition ratio	1:3	1:3

Note.--Dimensions in inches.
[a] Bases of lines were 6$\frac{1}{2}$ in. from bottom of panel.
[b] Rectangular outlines were $\frac{1}{2}$ in. wide luminous lines.

Each panel contained a variable and a standard line length. The nonrelational stimulus panel was of black cardboard with a luminous standard line on the left, and a 1 in. vertical slit on the right side into which the luminous variable line, mounted on a strip of black cardboard, was fitted. By manually raising or lowering this strip, the variable line length could be changed from 0 to 18 in. The

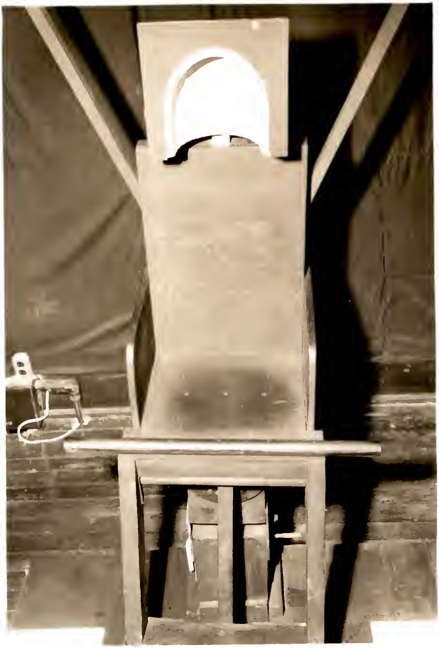

Fig. 1.--Tilting chair.

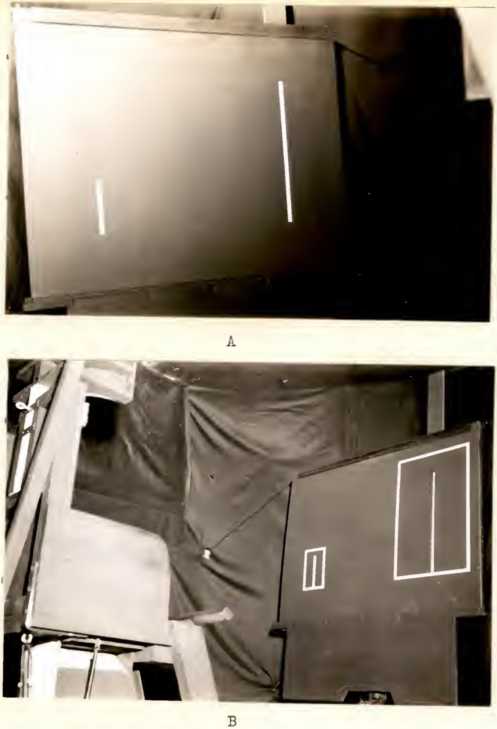

Fig. 2.--A. Nonrelational stimulus panel; B. Relational stimulus panel and tilting chair.

relational panel was of similar construction and dimensions, except that the standard luminous line and the slit into which the variable line fitted were inclosed in luminous outline rectangles.

Luminosity of the stimulus lines and rectangles was produced by the application of nonpigmented luminous paint to strips of white cardboard. Stimulus intensity was controlled by energizing the panel for 10 min. with two 75 watt neon lights immediately prior to use. Due to the spectral reflectance characteristics of the painted strips, and illumination source, the stimuli were a low intensity desaturated blue. The brightness level of the stimuli was low enough to avoid extraneous visual cues.

For the relational panel, the linear dimensions of the rectangle inclosing the variable line were three times larger than the standard rectangle, except for the widths of the rectangular outlines which were the same (see Table 1). On both panels, the variable lines were three times longer when set at their maximum length, than the standard lines, but here also the line widths were identical. Use of this 1:3 transposition ratio and similar line widths permitted comparison of present results to certain findings of Rock and Ebenholtz (1959). Although a 1:3 ratio with a standard line of 6 in. did not permit equidistant starting settings of the variable line (i.e. 12 in. maximum above standard and 6 in. below standard line length), the greater visual involvement required of

S to make a match warranted this selection. The greater distance above the standard value could be a source of constant error, but if so, it was the same for both the relational and nonrelational tasks.

Rock and Ebenholtz (1959) asserted that presentation of stimuli as in the Kunnapas (1955) experiment (i.e. side by side on a common background under full illumination) reduced context effect on size estimation, because the stimuli were viewed within a common frame of reference. In the Rock and Ebenholtz (1959) experiment, the luminous standard and variable stimuli were presented 180° apart in the dark. In the present experiment, the stimuli were presented side by side with a 2 ft. separation under dark conditions. Presentation of stimuli in this manner prevented the standard and variable lines and rectangles from being viewed within a common frame of reference (i.e. the panel boundary).

Criterion Variable

The stimulus panels, singly presented as required, were placed in front of S on the stimulus rack. The panels were viewed binocularly. For relational and nonrelational size estimates S's task was to equate the lengths of the variable and standard lines. On the reverse of each panel beside the track in which the variable line was moved, a scale was located to measure variable line length in 1/16 in. steps.

The variable line was presented to S in ascending and descending trials (method of average error). Following

Rock and Ebenholtz (1959), the variable line was initially set at its maximal length (18 in.) for a descending trial, and at its minimal value (0 in.) for an ascending trial. The E steadily and continuously moved the variable line until S was satisfied that it matched the standard line. If S overshot, readjustments were permitted.

One match, either an ascending or descending trial, was made each 30 sec. An electric timer provided these intervals, which consisted of an 8 sec. warning signal (buzzer) followed by a 22 sec. estimation period. During the warning period, E recorded the estimates, and made the proper initial setting of the variable line for the next trial. The estimation period allowed was considered sufficient to make careful judgments.

Experimental Variables

The four experimental variables and their values were selected because (1) their general significance had been shown in other experiments and/or, (2) they offered the possibility of interesting comparisons with the results of other related experiments. The variables and their values were as follows.

Surround. The two conditions for the surround variables, rectangles absent or present, have been previously described.

Direction of Body Tilt. Left lateral, right lateral, and forward medial, were the directions of body tilt employed.

Magnitude of Body Tilt. The magnitudes of body tilt selected for all three directions were 0, 15, and 30 degrees (M-0, M-15, and M-30, respectively).

To avoid the possibility that changes in phenomenal verticality with body tilt would affect size estimation, some control of phenomenal verticality of the stimulus lines under the various directions and magnitudes of body tilt was considered necessary. Phenomenal verticality for lateral tilt was accomplished by rotation of the panel containing the stimulus lines to an angular position on the side opposite a particular direction of tilt. To have some comparable change for forward direction the panel was raised upward from a (hypothetical) line extended directly outward from the center of S's face, since S's face was slanted downward when tilted forward. The amount of rotation or elevation of a panel was varied with the degree of magnitude associated with the tilt direction. The amounts were 2° for M-0, 4° for M-15, and 8° for M-30. These rotations approximate those suggested by the Werner et al. (1951) results. Any change in distance from S to the stimuli as a consequence of a panel elevation was less than one-half inch.

The panel was rotated (or elevated) 2° at M-0, so that each M-0 on the three directions would be orthogonal for purposes of analysis. To illustrate, if S was to be tilted in a left direction, on the M-0 value associated with this direction change, the panel was rotated 2° clockwise from the true vertical. For the M-0 value under a right direction change, the panel was rotated 2^{0} counterclockwise. Since these rotations were uniform with regard to the other magnitude rotations on either a left or right direction, it was possible to classify M-0 under a certain direction of tilt.

Duration of Body Tilt. An ascending and descending size estimate was made each minute of a 4 min. period on each treatment combination. These four 1 min. periods constituted the duration of bodily tilt values.

Order of Experimental Treatments

The combination of the values for the four experimental variables revealed 72 experimental treatments (three directions x three magnitudes x two surrounds x four duration intervals). In order to avoid fatigue effects and reduce intersubject variability, each _S_ was tested for all the values of magnitude, surround, and duration on one tilt direction only.

The order of treatments combined both randomization and counterbalancing. Subjects were randomly assigned to one of the three directions. Half of the subjects under each direction condition were randomly assigned an increasing (i.e. M-0, M-15, M-30) sequence of magnitude administration, and the other half a decreasing (i.e. M-30, M-15, M-0) magnitude sequence. With regard to surround conditions, on half the _S_s the relational and nonrelational order was randomly determined. For the other half, this order was reversed.

For the eight size estimates made during each 4 min. interval, a counterbalanced order (AD DA DA AD) of ascending and descending trials was used. This order, by averaging the two estimates made each minute, provided a comparable index of size estimation for the four duration intervals without the necessity of concern for ascending-descending trial differences.

Procedure

On entering the testing area, S was given a visual acuity check (Snellen chart) and randomly assigned to one of the treatment orders. Following assurance there was nothing harmful about the experiment, S was told the experiment concerned visual perception and invited into the dark room where the test equipment was located. Under the illumination of a 7½ watt red bulb, S was seated in the tilting chair at level position and the headrest adjusted. The red light was turned off and S sat in the chair for 10 min. with eyes closed in order to become dark adapted and accustomed to the chair. During this period, the nature of the task was explained, avoiding any reference to the fact that size estimates for lines within rectangles tended to appear larger than lines without rectangles. Allowing S to open his eyes momentarily, a practice demonstration was given on the nonrelational panel to assure that S understood the lines were to be matched with respect to each other and not necessarily any frame of reference in which presented. All Ss were instructed to keep their eyes closed at all times except when making size estimates.

To begin testing, S rose from his seat and stood beside the tilting chair while E made the necessary chair and panel adjustments. After 2 min. of standing, the warning buzzer sounded, S resumed his seat, opened his eyes and indicated for E to increase or decrease the variable line length for an equal match to the standard. Eight matches each 4 min. were then made, after which S rose and stood by the chair for 2 min. while the second surround panel was placed on the rack. The S was again seated and made eight more matches on the second surround condition. This cycle completed the judgments for the first magnitude of tilt. Similar procedures were carried out for the second and third tilt magnitudes. The timer which metered out the eight 30 sec. test trials also metered the 2 min. rest pauses between conditions. Through the use of the warning signal prior to each 22 sec. estimation period, after testing commenced no additional instructions from E were necessary except the request to stand after every eight matches. This arrangement also insured the four duration intervals were the same length.

In review, for the approximately 50 min. necessary to test an S on the two surrounds and three magnitudes for a particular direction of tilt, 5 min. were allowed for preliminary information and acuity check, 10 min. for adaptation and instructions, 24 min. for testing, and 12 min. for rest pauses between estimates.

Subjects

The Ss used were 36 male students, 12 for each tilt direction, from introductory psychology courses. Median age was 20.14 (M = 20.44) years with SD of 1.71. Each S had 20/20 corrected vision and no obvious equilibrium difficulties.

RESULTS

Main Analyses

An analysis of variance design modified from Lindquist (1953, pp. 292-297 ; Type VI) was used to test the effect of the experimental variables on size estimation. The results of this analysis are given in Table 2. Scores used for analysis were the averaged estimates of an ascending and descending trial made each minute. To facilitate computation all scores were rounded to .01 in. Because of the number and nature of the variables, $P = .05$ was adopted as an appropriate level of significance.

Since each S was tested only on one direction of tilt, direction was the between subjects variable. With regard to the choice of error term(s) for testing the significance of the within variable effects in Table 2, a Bartlett test for homogeneity revealed statistically significant differences between the separate within error variances ($\chi^2 = 211$; $df = 6$; $P < .001$). Due to the marked heterogeneity, the correct error terms to test the within variable effects were the separate error variances ($E_1[w]$ through $E_7[w]$), rather than the pooled error term (Lindquist, 1953, p. 297). For clarity of exposition and comparison purposes, F tests using both the pooled and separate within error variances are presented in Table 2, although the separate F tests were of primary concern.

Means and standard deviations for the more pertinent experimental conditions are presented in Table 3. Examination of the results in Table 2 and means given in Table 3 revealed that direction of tilt had no significant effect on size estimation. Although nonsignificant, the average size estimation for forward tilt was larger than size estimates for left or right tilt.

Regarding the within experimental variables, surround had a highly significant effect ($P < .001$) on size estimation, as shown by both the pooled and separate F tests in Table 2. Comparison of means in Table 3 showed that relational size estimates were approximately 3/16 in. larger than nonrelational estimates. In terms of constant error from the 6 in. standard line value, both relational and nonrelational determination resulted in overestimation of line length, with the relational overestimates larger.

On the separate error term test in Table 2, duration had a significant ($P = .03$) effect on size estimation. Examination of means reflected size estimates decreased with increased exposure to body tilt. With accuracy defined as a decrease in constant error of variable line settings from the 6 in. standard line value, accuracy of estimation increased with increasing duration.

TABLE 2

ANALYSIS OF VARIANCE OF EXPERIMENTAL VARIABLES WITH POOLED AND SEPARATE ERROR (w) TESTS

Source	df	MS	F	
Between Subjects	(35)	.64	---	
Direction Tilt (T)	2	.81	1.29	
Error (b)	33	.63	---	
			Pooled F	Separate F
Within Subjects	(828)	.05	1.25	---
Magnitude (M)	2	.06	1.50	.46
Surround (S)	1	7.31	182.75***	52.21***
Duration (D)	3	.06	1.50	3.00*
M X S	2	.02	.50	.50
M X D	6	.01	.25	.33
S X D	3	.09	2.25	4.50**
M X S X D	6	.06	1.50	3.00**
M X T	4	.16	4.00**	1.23
S X T	2	.01	.25	.07
D X T	6	.01	.25	.50
M X S X T	4	.03	.75	.75
M X D X T	12	.02	.50	.66
S X D X T	6	.03	.75	1.50
M X S X D X T	12	.01	.25	.50
Error (w)	(759)	.04	---	---
E_1(w) (MxSs)	66	.13	---	---
E_2(w) (SxSs)	33	.14	---	---
E_3(w) (DxSs)	99	.02	---	---
E_4(w) (MxSxSs)	66	.04	---	---
E_5(w) (MxDxSs)	198	.03	---	---
E_6(w) (SxDxSs)	99	.02	---	---
E_7(w) (MxSxDxSs)	198	.02	---	---
Total	863			

*$P < .05$
**$P < .01$
***$P < .001$

TABLE 3

MEANS AND STANDARD DEVIATIONS FOR THE PRINCIPAL CONDITIONS

Direction of Tilt:	Left	Right	Forward
M	6.21	6.28	6.32
SD	.217	.302	.259

Surround:	Relational	Nonrelational
M	6.36	6.18
SD	.278	.216

Magnitude of Tilt:	0°	15°	30°
Relational			
M	6.34	6.36	6.38
SD	.262	.276	.294
Nonrelational			
M	6.18	6.16	6.19
SD	.200	.192	.249
Total			
M	6.26	6.26	6.28
SD	.247	.258	.288

Duration:	1'	2'	3'	4'
Relational				
M	6.40	6.35	6.35	6.34
SD	.295	.292	.273	.269
Nonrelational				
M	6.16	6.22	6.16	6.16
SD	.200	.226	.219	.212
Total				
M	6.28	6.28	6.26	6.25
SD	.267	.269	.266	.257

Note.--Overall mean = 6.267.

There was a significantly different functional relationship between size estimation and duration for the two surround conditions, as shown by the significant ($P < .01$) S x D interactions in Table 2. Comparison of the relational and nonrelational mean estimates over minutes of duration in Table 3 showed that average relational size estimates decreased more consistently from the initial period of estimation, than the nonrelational. Except for a rise at the second minute interval, the mean nonrelational size estimates remained constant over duration.

Since degree of magnitude effects on size estimation constituted the main test for extension of the sensory-tonic theory to a more complex perceptual task, this variable was examined extensively. From Table 2 it was observed that the different degrees of magnitude had no significant effect on size estimation. Size estimates did not decrease with increased magnitude of body tilt. Although nonsignificant, examination of the total magnitude means in Table 3 showed that estimates under the greatest magnitudes of tilt (i.e. 30°) were slightly larger (.02 in.) than estimates made from an erect body position or 15° magnitude of body tilt.

Since the M x S x D interaction in Table 2 was significant ($P < .01$), the relational and nonrelational means over minutes of duration were examined at each degree of magnitude. These mean values are given in Table 4. These values, along with the combined surround means, are graphed in Figure 3. Assuming the function relating size estimation and duration to be linear, if lines of best fit were drawn by inspection through the array of means in Figure 3, the following observations were possible. At magnitudes 0° and 30°, for both relational and nonrelational estimation, the lines reflected a decrease in size estimates over duration of tilt. However at 15° magnitude, in contrast to the other two magnitude levels, the relational decrease was more distinct and the nonrelational estimates showed an increase. The combined surround lines all showed similarly slight decreases in size estimation over duration at each degree of magnitude.

TABLE 4

MEANS FOR RELATIONAL (R) AND NONRELATIONAL (NR) ESTIMATION OVER DURATION FOR EACH DEGREE OF MAGNITUDE

	Duration Periods			
	1	2	3	4
Magnitude 0°				
R	6.38	6.31	6.33	6.35
NR	6.17	6.21	6.18	6.14
Difference	.21	.10	.15	.21
Magnitude 15°				
R	6.43	6.37	6.33	6.30
NR	6.12	6.19	6.16	6.18
Difference	.31	.18	.17	.12
Magnitude 30°				
R	6.38	6.37	6.40	6.36
NR	6.20	6.25	6.14	6.17
Difference	.18	.12	.26	.19

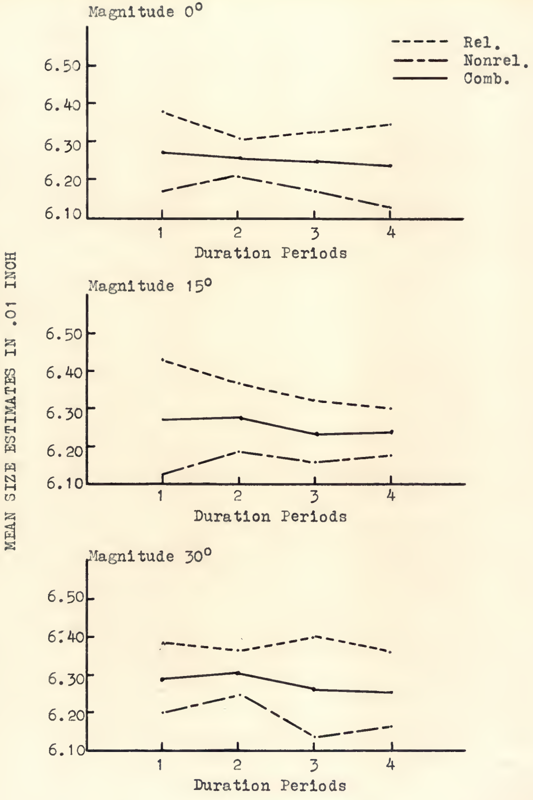

Fig. 3.--Surround means over minutes of duration at the three degrees of tilt magnitude.

Inspection of the differences between means in Table 4 revealed the average difference at 0° magnitude was less than at 15° or 30° magnitude. Since both the S x D and M x S x D interaction in Table 2 was significant, separate F tests were made of the S x D interactions at each level of magnitude, to examine any differences in S x D interactions at the different degrees of magnitude. As surmised from Figure 3, only the S x D interaction at 15° magnitude was significant ($F = 6.00$; df = 3 and 105; $P < .001$). One of the tilted body conditions (i.e. M-15) appeared to have more effect on the overall S x D interaction than the nontilted condition (i.e. M-0).

The nonsignificant interaction between magnitude and surround in Table 2 suggested similar functional relationships between size estimation and magnitude of tilt, for relational and nonrelational estimation. The magnitude relational means in Table 3 showed a slightly progressive increase in size estimation with increased magnitude. Additional evidence concerning the functions relating size estimation to degree of magnitude is offered by trend analyses that follow later.

In Table 2 it was observed that the interaction between magnitude and direction of tilt was significant ($P < .01$), when based on the pooled E(w) term. However this interaction was disregarded due to the marked heterogeneity of the separate error variances. In addition, the order of experimental treatments divided direction of tilt into two sequences of magnitude administration (see page 15). Since direction of tilt as given in Table 2 was confounded with sequence, it was necessary to analyze sequence and direction concomitantly to determine if the Table 2 results involving direction represented uncontaminated effects. Inclusion of sequence as another between subjects variable in the Table 2 analysis would have been unwieldy and made interpretation of the results difficult.

The significant M x T interaction in Table 2 also suggested additional analyses of magnitude effects, with heterogeneity of variance reduced. By collapsing the surround and duration variables within each degree of magnitude, the data used in the preceding Type VI analysis (Table 2) was reducible to other analysis of variance designs, with more stable scores available to investigate magnitude effects. Including sequence as another between subjects variable, an analysis of variance (Lindquist, 1953, pp. 281-284; Type III) was performed, using the sums of the combined scores within each degree of magnitude. The results of this analysis for the variables, direction, sequence, and magnitude of tilt, are given in Table 5, along with similar separate analyses results based on the relational and nonrelational data.

From the combined score analysis of Table 5 it was observed that again magnitude and direction of tilt effects were nonsignificant. There was no significant difference between the two sequences. The lack of direction and sequence effects and the nonsignificant interaction between direction and sequence suggested that the confounding of these variables was inconsequential to the direction of tilt results in Table 2, except for the pooled M x T interaction. The significant interaction between magnitude and sequence, and the nonsignificant interaction between magnitude and direction, given in Table 5, indicated the significant M x T interaction in Table 2 was due to sequence, rather than direction effects.

Means and standard deviations of the sequences and directions of tilt for the three degrees of magnitude are shown in Table 6. For the increasing sequence of magnitude administration, size estimates decreased with increased magnitude of tilt. For the decreasing sequence, size estimates were larger at 30° magnitude than at 0° or 15° magnitude. Independent or related sample t tests, as appropriate, revealed that none of these magnitude or sequence mean differences were significant.

Considered in terms of changes from the first magnitude to which exposed (i.e. 0° for the increasing sequence and 30° for the decreasing sequence), rather than in terms of increased magnitude, the sequence means in Table 6 indicated some cumulative adaptation effect occurred with repeated estimation magnitude. Size estimates became more accurate with repeated exposures to the different magnitudes of body tilt.

TABLE 5

ANALYSES OF VARIANCE FOR SEQUENCE, DIRECTION, AND MAGNITUDE OF BODY TILT

		Combined[a]		Relational		Nonrelational	
Source	df	MS	F	MS	F	MS	F
Between Subjects	(35)	5.12	---	2.15	---	.93	---
Sequence (Q)	1	1.54	.30	1.30	.60	.01	.01
Direction (T)	2	6.51	1.27	1.36	.63	1.94	2.13
Q X T	2	5.57	1.09	3.14	1.45	.60	.66
Error (b)	30	5.12	---	2.17	---	.91	---
Within Subjects	(72)	1.06	---	.32	1.03	.33	1.18
Magnitude (M)	2	.47	.51	.18	.58	.14	.50
M X Q	2	3.57	3.88**	.87	2.81	1.00	3.57*
M X T	4	1.32	1.43	.13	.42	.64	2.29
M X Q X T	4	1.86	2.02	.52	1.68	.51	1.82
Error (w)	60	.92	---	.31	---	.28	---
Total	107						

[a] Based on Σ of surround and duration scores within each degree of magnitude.

*$P < .05$

**$P < .03$

TABLE 6

MEANS AND STANDARD DEVIATIONS[a] OF SEQUENCES AND DIRECTIONS FOR DEGREES OF MAGNITUDE

		Magnitudes		
		0°	15°	30°
Sequences:				
Increasing (M-0,M-15,M-30)	M	6.30	6.29	6.25
	SD	.152	.215	.236
Decreasing (M-30,M-15,M-0)	M	6.22	6.22	6.31
	SD	.191	.133	.184
Directions of Tilt:				
Left	M	6.25	6.20	6.18
	SD	.128	.110	.104
Right	M	6.26	6.27	6.30
	SD	.178	.233	.300
Forward	M	6.27	6.31	6.37
	SD	.213	.165	.138
Total[b]	SD	.177	.182	.214

[a] Based on $\underline{\Sigma}$ of surround and duration scores

[b] Means given in Table 3.

Since surround as an experimental variable was disregarded in the combined score results in Table 5, separate analyses of variances were made to examine the direction, sequence, and magnitude effects when based solely on the relational or nonrelational data. From the separate analyses in Table 5 it was observed that none of the results were significant except the nonrelational M x Q interaction. This significant ($P < .05$) interaction suggested the combined surround M x Q interaction was primarily attributable to nonrelational estimation.

A Bartlett test applied to the combined score data used in Table 5 revealed marked heterogeneity among the magnitude variances on the different directions and sequences ($\chi^2 = 180$; df = 19; $P < .001$). Comparison of the means and standard deviations over degrees of magnitude in Table 6 suggested that a consequence of this marked heterogeneity was a definite correlation between the means and variances. To examine magnitude and direction of tilt effects on size estimation with the heterogeneity reduced, an analysis of variance based on logarithmic transformations was accomplished. This analysis failed to reveal any significant effects from magnitude or direction of tilt.

Since the parametric tests requiring assumptions of normality and homogeneity of variances failed to show any significant differences between the degrees of magnitude, a nonparametric test was employed to examine magnitude effects on size estimation. Based on the sum scores within each degree of magnitude (i.e. collapsing surround and duration as for the data in Table 5), Friedman's two-way analysis of variance by ranks (Siegel, 1956, pp. 166-172) was applied. Results of this analysis for overall magnitude (i.e. disregarding sequence and direction) were nonsignificant ($\chi_r^2 = 3.68$; df = 2; P = .20). None of the χ_r^2 values for the degrees of magnitude at the two sequences or three directions of tilt were significant. Degree of magnitude of body tilt had no significant effect on size estimation even when distribution free tests were used.

Trend Analyses

Various trend analyses were performed to examine the relational and nonrelational functions between size estimation and magnitude, and size estimation and duration. Trend analysis appeared particularly worthwhile for duration, since there are few studies showing the course of changes in visual task performance as a result of time of exposure to body tilt. The results of Table 2 showed size estimation was effected by duration but the previous analyses did not specify the functions relating these variables. Trend analyses offered confirmation and supplemental information for certain preceding findings concerning magnitude and duration, since such specific comparisons are more likely to detect any real differences than overall F tests (Ray, 1960, p. 165). Means pertinent to the trend analyses are given in Table 3.

Trend analyses were appropriate since both degrees of magnitude and duration intervals were equally spaced. Concerning the assumptions of normality and homogeneity of the within variances, Bartlett tests revealed all the within variances for the degrees of magnitude and duration intervals were homogeneous. Results of these homogeneity tests for the various surround conditions are given in Table 7.

TABLE 7

HOMOGENEITY TESTS OF THE WITHIN VARIANCES
FOR DURATION AND MAGNITUDE OF BODY TILT

	df	χ^2
Magnitude of Tilt:		
Relational	2	1.51
Nonrelational	2	3.13
Combined surrounds	2	1.36
Duration of Tilt:		
Relational	3	.31
Nonrelational	3	.82
Combined surrounds	3	.58

Note.--All P values are nonsignificant.

For magnitude, the trend analyses selected were to determine if the relationship between size estimation and degree of magnitude was a horizontal straight line, and if the relational and nonrelational functions were similar. To test the hypothesis of no trend, a trend test for repeated measures on the same S̲ was employed (Lindquist, 1947, p. 67), based on the sums of all the scores within each degree of magnitude. The results of the relational, nonrelational, and combined surround analyses are given in Table 8. Since these trend tests required the assumption that all Ss' regression lines have zero slope, regression coefficients (b_{yx}) based on the sum scores are also included. The coefficients were low enough to satisfy the assumption

TABLE 8

TREND TESTS OF SUCCESSIVE SIZE ESTIMATES OVER MAGNITUDES FOR RELATIONAL, NONRELATIONAL, AND COMBINED SURROUNDS

		Relational[a]		Nonrelational[b]		Combined[c]	
Source	df	MS	F	MS	F	MS	F
Magnitude (M)	2	.18	.55	.14	.41	.47	.44
Subjects (S)	35	2.15	6.52*	.93	2.74*	5.12	4.74*
M X S	70	.33	---	.34	---	1.08	---
Total	107						

$^{a}b_{yx} = + .07$

$^{b}b_{yx} = + .03$

$^{c}b_{yx} = + .10$

$*P < .001$

From Table 8 it was observed that none of the trend tests for magnitude were significant. This confirmed that the trend relating size estimation to magnitude was a horizontal straight line for relational, nonrelational, and combined surround estimation. These results concur with the nonsignificant magnitude and M x S interation in Table 2. Since the preceding trend analyses for all surround conditions failed to yield any evidence for significant differences in the degree of magnitude means, no further trend analysis was considered necessary to test for linearity of relationship.

An analysis of the trends among differences between relational and nonrelational estimation revealed that these trends were statistically indistinguishable over the degrees of magnitude (F = .23; df = 2 and 70; P n/s); the difference between relational and nonrelational estimation did not increase significantly with an increase in magnitude of tilt.

Since the S x D interaction in Table 2 was significant, trend analyses were performed in an effort to specify the nature of the relationships between size estimation and duration for the relational, nonrelational, and combined surround conditions. These analyses also examined the hypothesis that the function relating size estimation to duration was a horizontal straight line.

Since measures of size estimation for the two surround conditions were not made on different Ss (i.e. not on independent samples as frequently used in two factor trend analyses), a single factor trend analysis modified from Ray (1960, Ch. 14) was used to determine the functions relating size estimation to duration. This modification involved substitution of a single S for a matched group or block. The possibility of this modification is mentioned by Edwards (1960, p. 225) and Ray (1960, p. 105). The modified analysis was a more convenient and simplified technique than the Grant (1956) orthogonal polynomial method, yet was similar to the orthogonal coefficient technique described by Edwards (1960, pp. 148-152 ; 226-227).

The results of the analyses which specified the function between size estimation and duration for relational, nonrelational, and combined surround determination are given in Table 9. The accuracy of the modified procedure was verified by the Edwards (1960, pp. 226-227) technique, showing identical results. Since duration was significant for all the analyses in Table 9, the results concur with the duration effects found in Table 2. The significant F tests for duration in Table 9 indicated the trend relating size estimation to duration was not a horizontal straight line.

The linear component was significant ($P < .01$) for both the relational and combined surround conditions. For the nonrelational analysis, the quadratic component was significant ($P < .05$) and the cubic component highly significant ($P < .005$). In terms of functions relating size estimation to duration for the two surround conditions, the relational function was linear, and the nonrelational function, curvilinear, having both quadratic and cubic components. The forms of the relationship between size estimation and duration for relational and nonrelational estimation were significantly

TABLE 9

COMPARISON OF TRENDS RELATING SIZE ESTIMATES TO DURATION FOR RELATIONAL, NONRELATIONAL, AND COMBINED SURROUNDS

		Relational		Nonrelational		Combined	
Source	df	MS	F	MS	F	MS	F
Duration (D)	(3)	.22	3.14*	.34	4.80**	.33	3.00*
Linear	1	.49	7.00**	.04	.80	.82	7.45**
Quadratic	1	.08	1.14	.21	4.20*	.03	.27
Cubic	1	.08	1.14	.46	9.20***	.15	1.36
Subjects (S)	35	1.62	---	.69	---	3.84	---
Error (DxS)	105	.07	---	.05	---	.11	---
Total	143						

*P < .05
**P < .01
***P < .005

different, based on four duration intervals. No attempt was made to specify the mathematical function relating size estimation to duration since only four data points were available.

The preceding trend results were also pertinent to the significant M x S x D interaction observed in Table 2, and graphed in Figure 3. When the surround means over duration at the three degrees of magnitude in Figure 3 were examined previously, it was assumed the function relating size estimates to duration was linear. This assumption appeared appropriate for combined surround and relational estimation, but inappropriate for nonrelational estimation. In addition, body tilt (i.e. M-15 and M-30) and nontilt (i.e. M-0) conditions seemed to affect the form of the nonrelational size-duration relationship differently. The shape of the curves at 15° and 30° magnitude suggested nonrelational size estimates tended to oscillate in some cyclic manner over duration (e.g. sinusoidal). Comparison of the nonrelational curves in Figure 3 at 15° and 30° magnitude reflected an increase in the amplitude of this oscillation with increased magnitude.

DISCUSSION

The present results will be discussed and evaluated in terms of the hypotheses from which this study started (see page 5).

1. Surround. It was hypothesized that relational size estimates would be larger than nonrelational estimates, and that this relation holds even when the body is tilted. This hypothesis was confirmed. (Tables 2 and 3.)

A comparison of the standard to variable line ratios under rectangular conditions revealed the relational effect was more pronounced in the Rock and Ebenholtz (1959) than the present experiment. The present relational results agree more closely with the Kunnapas (1955) than with the Rock and Ebenholtz (1959) results.

An examination of the methodological differences in these experiments suggested certain reasons to account for this discrepancy between the present and Rock and Ebenholtz (1959) experiments. A likely reason, from evidence which follows, was the difference in distance between the standard and variable configurations. In the Kunnapas (1955) and present experiments, the stimulus configurations were presented side by side and the variable to standard line ratios were approximately of the order 1.1:1. In the Rock and Ebenholtz (1959) experiment, the standard and variable configurations were presented 180° apart on each side of S and the variable to standard line ratio was approximately 2:1. Comparison of the smaller ratios when the stimuli were viewed side by side, to the larger ratio when S viewed successively the stimulus configuration of the left and on the right side, suggests that the error of estimation decreases with a decrease in the distance between the two configurations. That the relational effect may vary proportionally with the distance between the configurations suggests a possibility for fruitful research.

2. Direction. The hypothesis was supported that size estimation is unrelated to direction of body tilt. Size estimates under left, right, and forward directions were not significantly different. (Table 2.) The present findings were in accordance with the Solley (1956) and Werner et al. (1951) results, which found left or right directions of tilt had no effect on perceptual judgment.

The lack of direction of tilt effect was consistent with regard to the other variables. The only variable which seemed to interact significantly with direction, was magnitude. On an initial analysis (Table 2) this interaction was disregarded due to marked heterogeneity of variance. However, making allowance for the marked heterogeneity by doubling the probability level, the interaction still appeared significant ($P < .02$). Additional analyses (Table 5) based on more stable scores suggested the interaction was an artifact, due to the order of experimental treatments (i.e. sequence of magnitude administration) rather than direction of tilt effects.

3. Magnitude. A variety of analyses (analyses of variance, log transformations, nonparametric, and trend) failed to reveal any evidence concerning magnitude effects on size estimation which substantiated the predictions based on the Werner et al. (1951) and Comalli et al. (1959) results. The hypotheses that size estimates differ significantly for different magnitudes of tilt, and that relational or nonrelational estimates decrease with an increase in the degree of tilt magnitude, were rejected. Trend tests indicated the function relating size estimation to magnitude was a horizontal line. Using magnitude as a criterion, the attempt to generalize the sensory-tonic theory to a more complex perceptual category, size estimation, was unsuccessful.

Because visual size estimation as presently assessed was not amenable to prediction by the sensory-tonic theory, the present findings were not in accord with the results of several other sensory-tonic complex judgment experiments (Wapner & Werner, 1957), which found critical flicker frequency, depth perception, brightness thresholds, and motion perception were affected by asymmetrical body stimulation. The discrepancy between these studies and the present experiment suggested consideration of possible causes to account for the present contradictory magnitude results.

Four methodological procedures in the present experiment may have been responsible for the different results. The partial body support arrangement of the tilting chair (i.e. buttock supports), may not have caused maximum muscular involvement when tilted. Werner et al. (1951) used 15° and 30° magnitudes of tilt on both supported and nonsupported conditions, with the latter more effective. A nonsupported arrangement may have been preferable to maximize magnitude effects, but to do so would have confounded apprehension of falling with magnitude of tilt. Since Werner et al. (1951) found a supported condition affected degree of displacement of apparent verticality, the arrangement selected should still be expected to yield the predicted results.

Another design feature which could have affected the present results was the manner of stimulus presentation. The evidence favoring rotation of the panels to control phenomenal verticality of the stimulus lines seems substantial. Werner et al. (1951) showed that body tilt affected apparent verticality, and various experiments (Pollock & Chapnis, 1952; Shipley, Nann, & Penfield, 1949) demonstrated line inclination affected apparent length. In addition, if the stimulus panel had been placed in a fixed position in the frontal plane, while not so clearly stated appears to be the case in the Werner et al. (1951) experiment, rather than directly in front of S's face as in the present experiment, the distance from S to the stimuli would have varied with the degree of magnitude, introducing distance as a factor affecting size estimation.

The third methodological factor which may have influenced the present magnitude results was the systematic order of degree of magnitude administration (i.e. sequence). It is possible that sequence biased magnitude effects, such that a random order of magnitude presentation would have been preferable. In contrast, Solley (1956) cautioned against the random order of conditions presentation in body tilt experiments, when repeated measures are made on the same S. The present sequence results, which revealed a definite increase in accuracy in size estimation with repeated measurements over magnitudes (especially so for nonrelational estimation), is in accordance with the Solley (1956) precaution. Use of a random magnitude order over the present order must be weighed against the evidence of some cumulative change or practice effect with repeated measures over magnitude. Randomization, as compared to some sequential order, would have permitted the cumulative effect to occur without an opportunity for its examination.

The fourth factor which may partially account for the present magnitude results was the 2 min. pause between each magnitude administration. If S were moved immediately from one degree of magnitude to another, different magnitude effects may have been obtained. While there appears to be no systematic studies concerning the effect of the interval between repeated exposures to body tilt on perception, various studies (Pearson & Hauty, 1959; Solley, 1956) investigating the effect of practice on perceptual judgment, have used shorter intervals between exposures (e.g. 5 sec.) than in the present experiment.

The 2 min. interval may also have affected the increase in accuracy of estimation with repeated exposures to the different magnitudes (i.e. the sequence effect). The advantage of a rest interval between repeated exposures to tilt over immediate movement from one magnitude to another, may be comparable to the superiority of distributed over massed practice. If such is the case, immediate movement from one degree of magnitude to another may tend to reduce the sequence effect found in the present experiment.

4. Duration. It was hypothesized that accuracy of size estimation increases with increased duration of body tilt. The present duration results confirmed this hypothesis. This finding seems to contradict the prediction by Mann and Passey (1951) that errors in perceptual

judgment increase slightly for tilt exposure times longer than one minute. Considering the difference in perceptual judgments required in the present and Mann and Passey (1951) experiments, the discrepancy between the studies suggests that the relationship between perceptual judgment and duration of tilt exposure may vary with the task.

In addition to task differences, the present results also offer a possible explanation why the Mann and Passey (1951) prediction, based on an extrapolation from estimates made each 10 sec. over a 65 sec. duration period, was not upheld. Examination of certain trends at the different tilt magnitudes revealed nonrelational estimates tended to oscillate over the four minute tilt duration periods. The Mann and Passey (1951) duration interval may have been too short to detect this oscillation which occurred with longer duration intervals.

When duration is regarded as inspection time of a visual stimulus, the present results reflect an increase in visual sensitivity with continued visual stimulation. If the duration intervals are considered as practice trials, the increase in accuracy of estimation over duration may be taken to suggest some perceptual learning occurred. Considered as practice trials, the present duration results are in accordance with the Pearson and Hauty (1959) and Solley (1956) results, which found accuracy of perceptual judgment increased with practice.

Generally the results of the present experiment indicate that surround effects should be considered in studies examining the effects of duration of body disorientation on perceptual judgment. A difference in functional relationships between perceptual task performance and duration, for relational and nonrelational determination, has been demonstrated. This difference may be applicable to other complex perceptual tasks. While the lack of body tilt effect on size estimation suggests that certain kinesthetic and proprioceptive stimulation may have a minor influence on visual perceptual judgments, the present duration results suggest that if such sustained stimulation does affect visual judgments, for nonrelational estimation this effect may be erratic.

SUMMARY AND CONCLUSIONS

This study investigated the effects of duration, direction, and magnitude of body tilt, on the relational and nonrelational estimation of line length. Relational estimates were made from standard and variable lines inclosed in luminous rectangles, and nonrelational estimates from lines not so inclosed. Thirty six male Ss matched a variable length line to a 6 in. standard line for four consecutive 1 min. intervals on each surround condition, while seated in a chair tilted 0, 15, and 30 degrees in either a left, right, or forward direction. The degrees of magnitude were administered in an increasing or decreasing sequence to determine if a practice effect occurred with repeated exposures to different magnitudes of body tilt. The stimuli were presented directly in front of S's face on all conditions. Phenomenal verticality of the stimulus lines was controlled for the various degrees of tilt.

The study was generally outlined within the framework of certain results from Rock and Ebenholtz (1959) on size estimation, and the Werner and Wapner (1949) sensory-tonic theory of perception. For certain hypotheses made, the following results were obtained.

1. Relational size estimates were significantly larger than nonrelational size estimates, and this relation held even when S was tilted in different directions and magnitudes.

2. Left or right lateral and forward medial directions of body tilt did not affect size estimation differentially.

3. A variety of analyses failed to reveal any magnitude of tilt effects on size estimation to substantiate certain predictions based on the sensory-tonic theory. The hypotheses that size estimates differ significantly for different magnitudes of tilt, and that relational or nonrelational estimates decrease with increased magnitude of tilt, were rejected. A trend analysis revealed the function relating size estimation to magnitude was a horizontal straight line. Examination of the sequence of magnitude administration revealed an increase in the accuracy of estimation with repeated estimates over the degrees of magnitude.

4. Duration of body tilt significantly affected size estimation. Accuracy of size estimation increased with increased duration of tilt. There was a significant interaction between surround and duration. Trend analyses revealed the function relating relational size estimation to duration was linear, and the nonrelational function nonlinear. The nonrelational function seemed to oscillate under conditions of body tilt, and the amplitude of this

oscillation tended to increase with increased magnitude of tilt.

The surround results were discussed in terms of the distance between standard and variable configuration effects, in the absence of a common frame of reference for the stimuli. Four methodological procedures were considered, which may have affected the nonsignificant magnitude results. The significant duration effects were considered in terms of the functions relating relational and nonrelational estimates to time of exposure. Comparison of the present duration results to certain relevant experiments suggested the relationship between perceptual judgment and duration may vary with the task. The surround and duration effects and their interaction suggest the advisability of considering these variables in experiments involving body disorientation.

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BIOGRAPHICAL SKETCH

Joe Thomas Hazel was born 9 November 1924 at Dawson, Georgia. He graduated from Spalding High School, Griffin, Georgia, in May, 1942, and attended Oglethorpe University for one year. From 1943 until 1946 he served in the United States Navy amphibious forces in the Pacific. Following his discharge from the navy, he entered Mercer University and received the degree of Bachelor of Arts in 1948. For a year he worked for the Bibb Manufacturing Company, Macon, Georgia, then attended Emory University, the University of Georgia, and Mercer University, receiving a Master of Education degree in 1951. He was recalled to active duty with the United States Air Force during the Korean war and has continued on active duty until the present time. During a part of this period he continued to study towards the degree of Doctor of Philosophy in psychology at Trinity University, Texas, and Ohio State University. In September 1960 he enrolled in the Graduate School at the University of Florida.

Joe Thomas Hazel is married to the former Patricia Joaan Kelly and is the father of five plus children. He is a member of the American Psychological Association.

This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of that committee. It was submitted to the Dean of the College of Arts and Sciences and to the Graduate Council, and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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